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FIRE ENDURANCE TESTS OF PREFABRICATED EXTERIOR WALL PANELS

by

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Fire Endurance Tests of Prefabricated Exterior Wall Panels

Test Report No. TC10219-83:FP3288

ABSTRACT

Two fire tests of prefabricated exterior walls were made at the National Bureau of Standards and two at a laboratory in the Netherlands to provide data for comparisons of the four constructions. Certain deviations in the Standard Test Methods, made necessary by the design of the Netherlands test furnace, were carried through all the tests. The tests do not provide the basis for standard fire ratings because of these deviations but show the relative performances of the four constructions under essentially equal test conditions.

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1. INTRODUCTION

In compliance with a request of May 25, 1954 (file E06VF) from the Corps of Engineers, Northeast District, two fire endurance tests of prefabricated panels for exterior walls were performed and two other fire tests of different panels for the same purpose were witnessed. The latter tests were conducted at the T. N. O.[1] Fire Research Laboratory, Delft, Holland.

The tests were made to provide data for comparisons among the four constructions tested, both as to fire resistance and as to the extent of repairs which would be necessary to make the assemblies fit for reuse.

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1. Technich Natuuruetenschalletigt Onderzoek (Central National Council for applied Scientific Research in the Netherlands)

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2. TEST SPECIMENS

The four constructions tested, in order, were:

Test 1. A hollow wall with an air space of about 2 in. (5 cm) between the inner an outer faces. The outer face consisted of precast high density concrete channel slabs with transverse ribs. Each slab was 10 ft. 6 in. (320 cm) high, 2 ft. 5½ in. (75 cm) wide, about 2 in. (5 cm) thick through the web and about 5.9 in. (15 cm) thick through the channel flanges and transverse ribs. The exterior sides of the flanges were formed to fit the flanges of the adjoining slabs in a tongue-and-groove system. The slabs were cast in forms on a shock table and shocked repeatedly to obtain the high density. The inner face consisted of a pressed board of wood shavings bonded with portland cement which was coated on both sides with about 3/4 in. of a portland cement and sand mixture, giving an overall thickness of about 4 in. The total thickness of the test specimen was about 12 in. The details are shown in figure 1.

Test 2. A sandwich wall with 2 in. of mineral wool insulation between the inner and outer faces. The outer face was of the same type materials and design as that in test 1. The inner face consisted of pumice concrete slabs 4 in. thick. The details are shown in figure 2.

Test 3. A wall consisting of three prefabricated panels, each of which was 9 ft.11 3/4 in. high, 2 ft. 8 in. wide, and 4 3/4 in. thick, overall. Each panel consisted of a rectangular wooden frame to one face of which had been attached a sheet of 18 gage steel plate which projected on both sides of the frame and was bent to form interlocking joints with neighboring panels. The interior of the 3 in. deep wood frame had been filled with 9 lb/ft^3 density mineral wool after which a corrugated sheet of 22 gage steel, coated with zinc, asbestos felt and a heavy asphaltic solution and aluminum painted on the outer side, had been attached to the other face of the frame. The mineral wool did not fill the 1 3/4 in. deep corrugations. The joints between panels in the interior or flat steel face were caulked and those in the exterior or corrugated face were stuffed with mineral wool and covered with full height 6 in. wide strips of the corrugated facing during erection. The details are shown in figure 3.

Test 4. A wall consisting of four prefabricated panels, each of which was 10 ft. high, 2 ft. wide, and 4 in. thick. Each panel consisted of a wood frame 9 ft. 4 3/4 in. high by 1 ft. 11½ in. wide by 3½ in. thick which had been faced on the interior side with ¼ in. plywood clad with zinc coated steel and on the exterior side with ¼ in. plywood clad with aluminum. The facings had been backed with asbestos paper and the space between facings filled with a glass fiber insulation. The interior face projected 3 5/8 in. above the wood frame and the exterior face 3 5/8 in. below, each backed with 3/4 in. additional plywood. These projecting lips had predrilled holes and eyelets for lag screws by which the panels were secured to 3 by 3 5/8 in. transverse sills at top and bottom during erection. All the surfaces of the wood components had been coated with a fire retardant paint except the metal clad faces of the plywood. The panels were tied together at erection by the sills and by 3/4 in. pipes which went through all four panels parallel to the faces near the top and bottom. The details are shown in figure 4.

3. TEST METHODS AND EQUIPMENT

It had been requested that the tests be performed to provide data for comparison of the various constructions. Therefore, the test conditions and methods were kept as nearly identical as practicable for each test. Wherever possible, the Standard Methods of Fire Tests of Building Construction and Materials, ASTM E119-53 were followed. The furnace fires were controlled to produce temperatures close to those specified in A119-53, which include: 1000° F (538° C) at 5 min., 1300° F (704° C) at 10 min., 1550° F (843° C) at 30 min., 1700° F (927° C) at 1 hr., 1850° F (1010° C) at 2 hr., and 2000° F (1093° C) at 4 hr. The end point criteria followed were those applicable to non-bearing walls and partitions. They provide that the fire endurance limit shall be determined by any of the following:

1. The average temperature on the unexposed surface increases 250 degrees F above its initial value.

2. The temperature at any one point on the unexposed surface increases 325 degrees F above its initial value.

3. Flames or gases hot enough to ignite cotton-waste pass through the wall.

Certain deviations from the Standard Test Methods were necessitated by the test furnaces. Tests 1 and 2 were made in the wall test furnace of the T. N. O. Laboratories at Delft, Holland, shown in figure 5. This furnace was such that the specimen size was about 7 ft. 6 in. wide and 10 ft. 6 in. high. The furnace temperatures were measured by five chromel-alumel thermocouples symmetrically distributed throughout the furnace chamber. The junctions were bare and were located about 3 in. from the exposed surface. The unexposed surface temperatures were measured by five chromel-alumel thermocouples whose junctions were placed under 6 in. square falted asbestos pads, four of which were symmetrically distributed over the surface and the fifth placed over a joint between panels. Tests 3 and 4 were made in the wall test furnace of the National Bureau of Standards in Washington. The test frames ordinarily required a specimen 10 ft. high and 16 ft. wide but filler walls were built in to reduce the latter dimension to accomodate test specimens 8 ft. wide, thereby approximating closely the frame size of the Delft furnace. Therefore, the exposed areas of all four test specimens were approximately equal but were less than the minimum specified in the Standard Test Methods. Eleven chromel-alumel thermocouples were distributed symmetrically over the unexposed surface with their junctions under 6 in. square felted asbestos pads 0.4 in. thick. The numbers and placement of thermocouples on the unexposed surfaces of the four test specimens varied because of the available equipment and the number of panels and joints and other construction details, but were considered equivalent. No hose stream tests were made on any of the specimens.

4. RESULTS

4.1 Test 1

Test of precast shocked concrete outer face and cement coated fiber board inner face with 2 in. air space between. During the first 40 min., slight amounts of smoke and steam issued from joints; at 45 min., 2 explosions, cement coating of inner face fell off from core and covered observation ports; 50 min, another explosion; 53 min., fourth explosion; 2 hrs., fifth explosion; 2 hr. 10 min., hairline cracks in unexposed surface of center panel, upper section; 2 hr 20 min., gas off.

Immediately after the gas was turned off, the test specimen and frame were removed from the furnace. The insulating interface panel in the center and portions of those in either side had fallen into the furnace chamber. The only damage to the concrete outer face was a spalled spot about ½ in. deep and 6 in. diameter in the center of the upper section of each panel. Deflections of the outer face were negligible.

The control of the furnace temperature was such that the exposure severity was 89 percent of standard. The fire endurance limit was determined by temperature rise of 325 degrees F at one thermocouple on the unexposed surface at 2 hr. 9 min. The thermocouple was on the face of the center panel. If the correction formula in 4119 is applied to the temperatures indicated by the bare thermocouples, the correction is minus 3 min. Therefore, the corrected fire endurance is 2 hr. 3 min. The temperatures measured during the test are shown in figure 5.

4.2 Test 2

Test of precast and shocked concrete outer face, mineral wool insulation, and precast pumice concrete inner face. Steam issued from the joints during the first 1 hr. 55 min. and slight amounts of smoke issued throughout the remainder of the test. Hairline cracks were observed in the unexposed surface at 1½ hr. and after about 3 hrs. the panels displayed a warped appearance. The gas was turned off at 3 hr. 46 min.

Immediately after the gas was turned off, the frame and specimen were removed from the furnace. The center pumice panel and portions of those on either side had melted down; the mineral wool was in place except for the center section behind the area of melted pumice. The outer concrete face was undamaged and recovered from the deflections upon cooling.

The control of the furnace was such that the fire exposure severity was 90 percent of standard. The fire endurance limit was determined at 3 hr. 30 min. by temperature rise of 325 degrees F at one thermocouple located on the unexposed face of the center panel in the upper half. If the correction formula in 4119 is applied to the temperatures as indicated by the bare furnace thermocouples, the correction is minus 3 min. Therefore the corrected fire endurance is 3 hr. 33 min. The temperatures measured during the test are shown in figure 6.

4.3 Test 3

Test of mineral wool filled metal faced prefabricated wall. At 5½ min., flames into furnace from one joint between panels, on exposed side; 6½ min., flames into furnace from other joint, exposed metal faces of all panels bowed toward flame; 1 min., yellow smoke from joints in unexposed surface; 13 min., flames into furnace from joints in exposed face almost out; 15 min., and after, repeated popping sounds; 31 min., flames out of furnace along top edge of specimen; 45 min., paint and or bituminous coating on upper 1/3 of unexposed face blistered; 1 hr. 1 min., gas off.

Immediately after the gas was turned off, the test frame was removed from the furnace. The exposed face of the specimen was badly warped and a bright glow or flames in the interior were visible through the joints. The specimen was removed from the frame, the exposed faces removed from the panels and the fires in the interior extinguished with water. The insulation in the upper 3 to 4 ft. had slipped down, into the space resulting from the bowing or puffing out of the exposed face. The wood frame and insulation were badly charred.

The furnace control was such that the fire exposure severity was 98.8 percent of standard. The fire endurance was limited to 37 min by 325 degree F temperature rise at the thermocouple on the unexposed surface. This thermocouple was located on the cover strip of one of the joints between panels. The applicable correction was minus 1 min. making the corrected fire endurance 34 min. The temperatures measured during the test are shown in figure 7.

4.4 Test 4

Test of metal clad plywood faced wall filled with glass fiber insulation. During the first 2 min., repeated popping; 3 min., voluminous flames into furnace from joints in exposed face, metal face bulged toward flame, smoke from joints in unexposed face; 5 min., offset of ¼ in. along joint in unexposed face as north panel bowed out; 21 min., bright glow or flames in interior of north panel visible through joint in exposed face; 27 min., joint in unexposed face between north and north-center panels open ¼ in., 34 min., popping sound, most of unexposed face warped; 48 min., glow visible from unexposed side in

north joint; by min., cotton waste over north joint ignited; 31 min., flames through north joint; 35 min., flames from all joints, gas off.

Immediately after the gas was turned off, the test frame was removed from the furnace. The flame still issued from the joint in the exposed surface and interior glow was visible through others. The specimen was removed from the test frame, the exposed face scraped and the interior fires extinguished. The wood and insulation were replaced and the latter put wet to keep it in its original position.

The furnace control was such that the fire exposure severity was 110.2 percent of standard but no correction was applied to the fire endurance which was limited to 40 min. by the ignition of cotton waste in the unexposed surface near the joint between panels. The temperatures measured during the test are shown in Figure 7.

5. DISCUSSION

5.1 Deviations from Standard Test Methods

The only provision of the standard test methods (ASTM E119-53) that was not complied with in any of the four tests was the fact that the overall sizes of the specimens were less than the minimum specified. The specimens of tests 1 and 2 were not subjected to the hose stream test because the standard hose and nozzle were not available at the Delft laboratory. The specimens of tests 3 and 4 were not subjected to the stream tests because such tests are not required for fire endurance less than 1 hr.

The fact that the specimens were less than minimum size does not permit the use of the test results as data for standard fire ratings, and probably influenced the results obtained. The effect of fire exposure on the structural stability of walls may seem to depend primarily upon fixedness in the flanges of the walls. However, since the sizes of the four test specimens were as nearly equal as practical, the size should not lower the value of these tests for comparisons with one another, or with tests of other specimens of the same size.

The placement of the furnace thermocouples for tests 1 and 2, at the Delft laboratory differed from the specified standard in that the thermocouples were not encased in pipes and were about 3 in. from the exposed face rather than 6 in. The bare junctions would lead to higher temperature indications because the pipes and their thermal lag were eliminated. Previous experience has indicated exposure severities indicated by bare thermocouples differed by about 7 percent from those indicated by encased thermocouples of the same kind. The effect of the placement of the thermocouple junctions about 3 in. from the exposed surfaces should be small since the overall depth of the furnace chamber was only about 11 in. Temperature variations along the depth in such a furnace should be less than or, at worst, equal to those that might exist in a deeper furnace chamber.

These deviations from the Standard Test Methods and the variations between the two test furnaces were such that, for the purpose of the comparisons for which the tests were requested, their effects should be small. However, if fire resistance ratings should be desired for the various constructions tested, it would be necessary to perform further tests which would be in full compliance with the Standard Test Methods.

5.2 Repairs Necessary for Reuse

At or before the ends of the tests, the individual test specimens had been damaged to the extent that repairs or replacement would be necessary. The conditions of the specimens during the tests would apparently require:

Test 1. The inner face would have to be replaced after a standard 2 hr. fire exposure or equivalent and the outer face panels should be patched but could be used as is.

Test 2. The inner face and the mineral wool insulation between the faces would have to be replaced but the outer face panels would probably be undamaged after a standard 3½ hr. fire exposure, or its equivalent.

Test 3. The complete wall panels would have to be replaced after a ½ hr. standard fire exposure, or equivalent.

Test 4. The complete wall panels would have to be replaced after a 3/4 hr. standard fire exposure, or equivalent.

Table 1. Degree of Compliance with Standard Test Methods (E119-53)

Item	E119 Requirements	N. B. S. Tests	N. B. S. Tests
Size	100 ft.^{2}	78 3/4 ft.^{2}	80 ft.^{2}
Least Dimension	9 ft.	7½ ft.	8 ft.
Furnace thermocouple protection	encased	bare	encased
Furnace thermocouple number	9 minimum	5	12
Furnace thermocouple exp. length	12 in. min.	8 apprx.	over 12 in.
Furnace thermocouple distance from exposed face	6 in.	3 in. apprx.	12 in. apprx.
Unexposed surface thermocouples number	5	5	11
Unexposed surface thermocouples protection	6 in. square pads	6 in. square pads	6 in. square pads

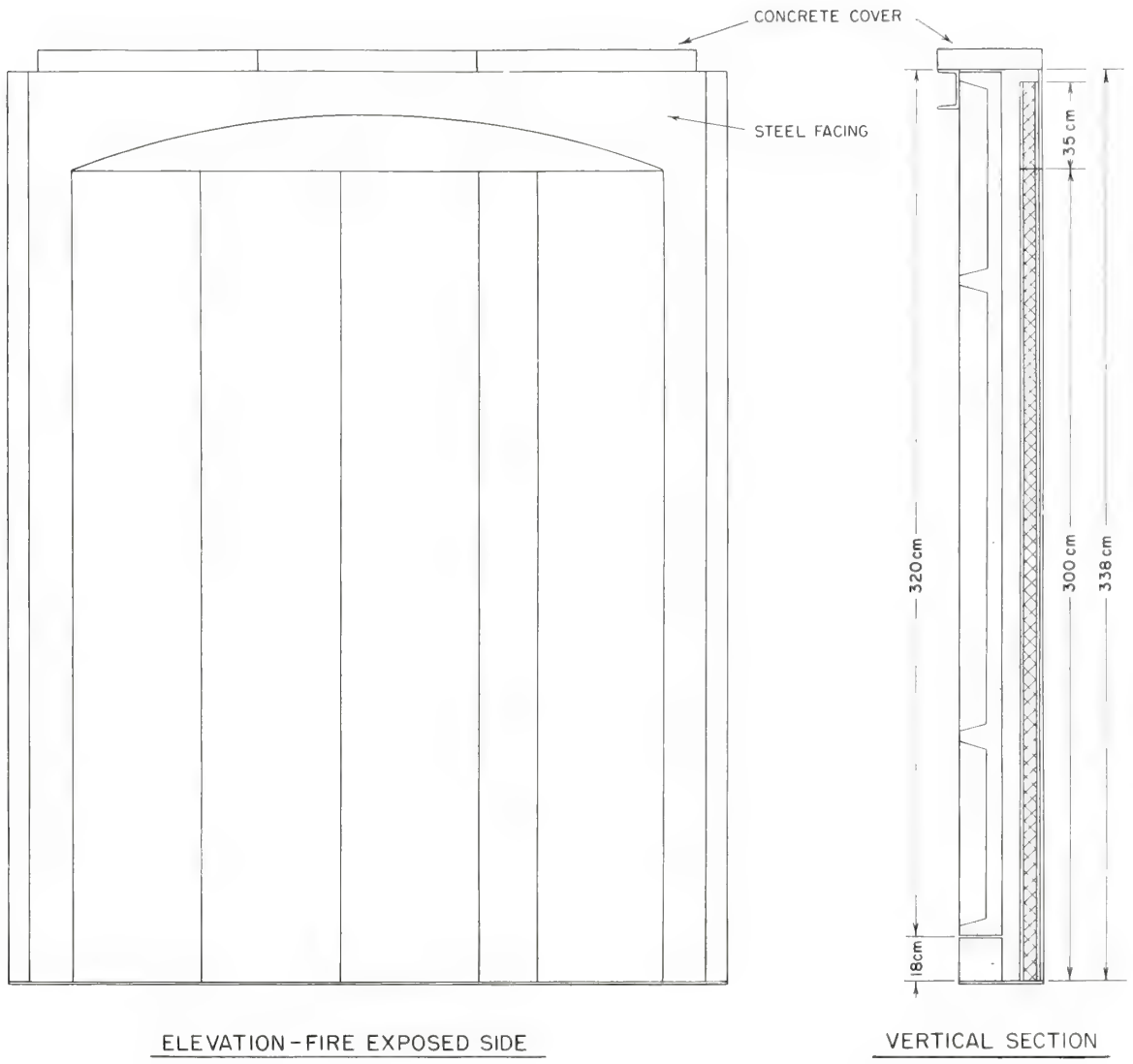
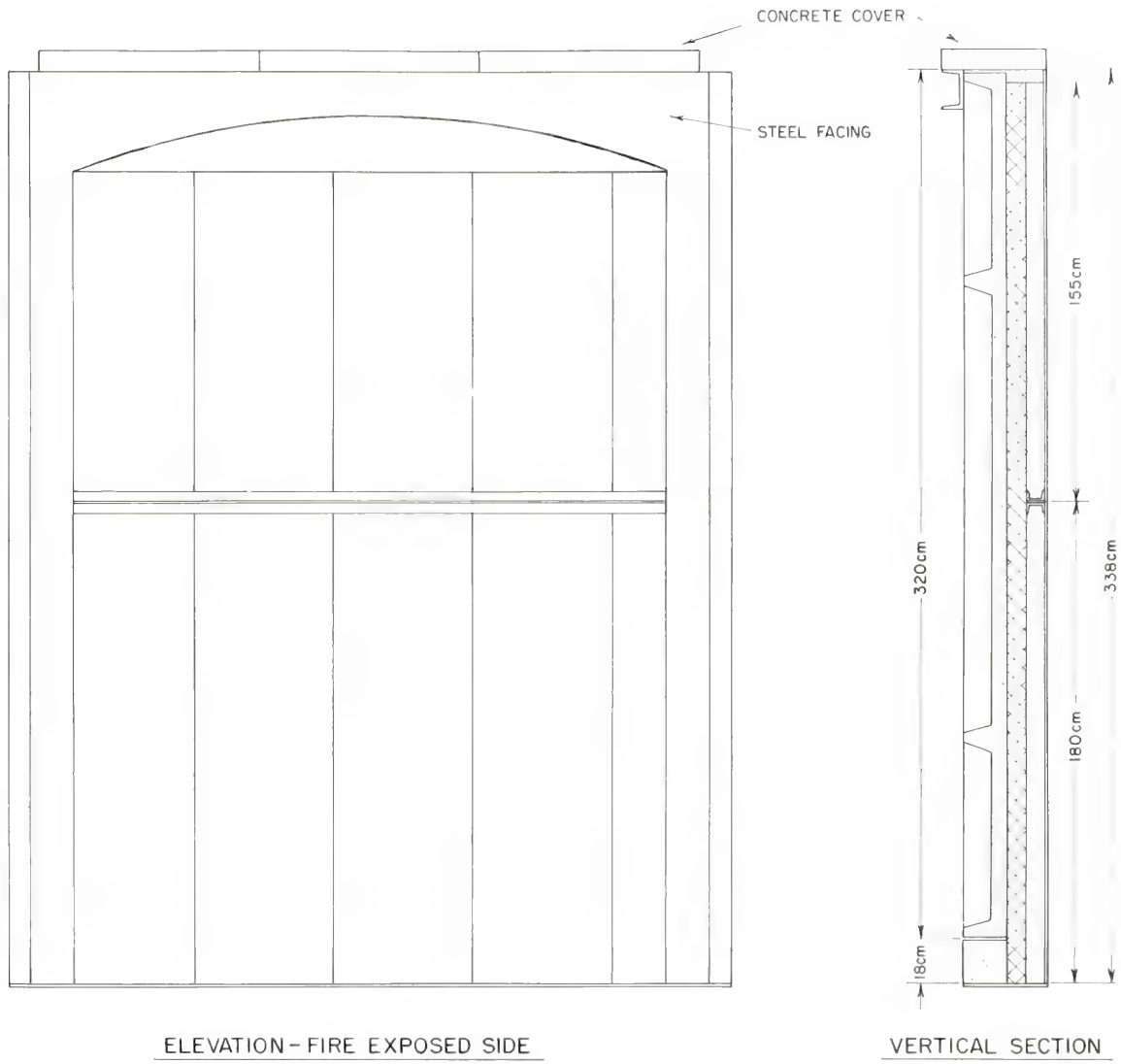


FIG. 1 CONSTRUCTION DETAILS OF TEST PANEL NO. 1



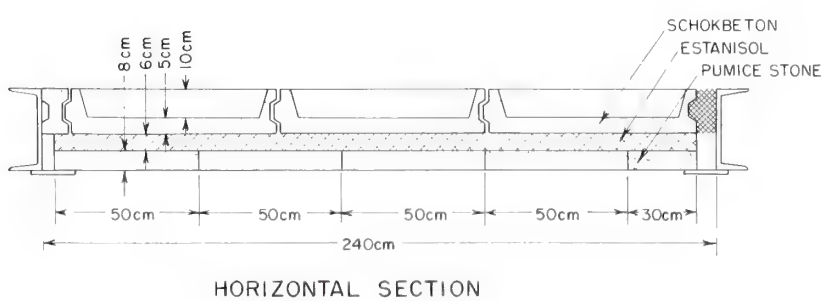


FIG. 2 CONSTRUCTION DETAILS OF TEST PANEL NO.2

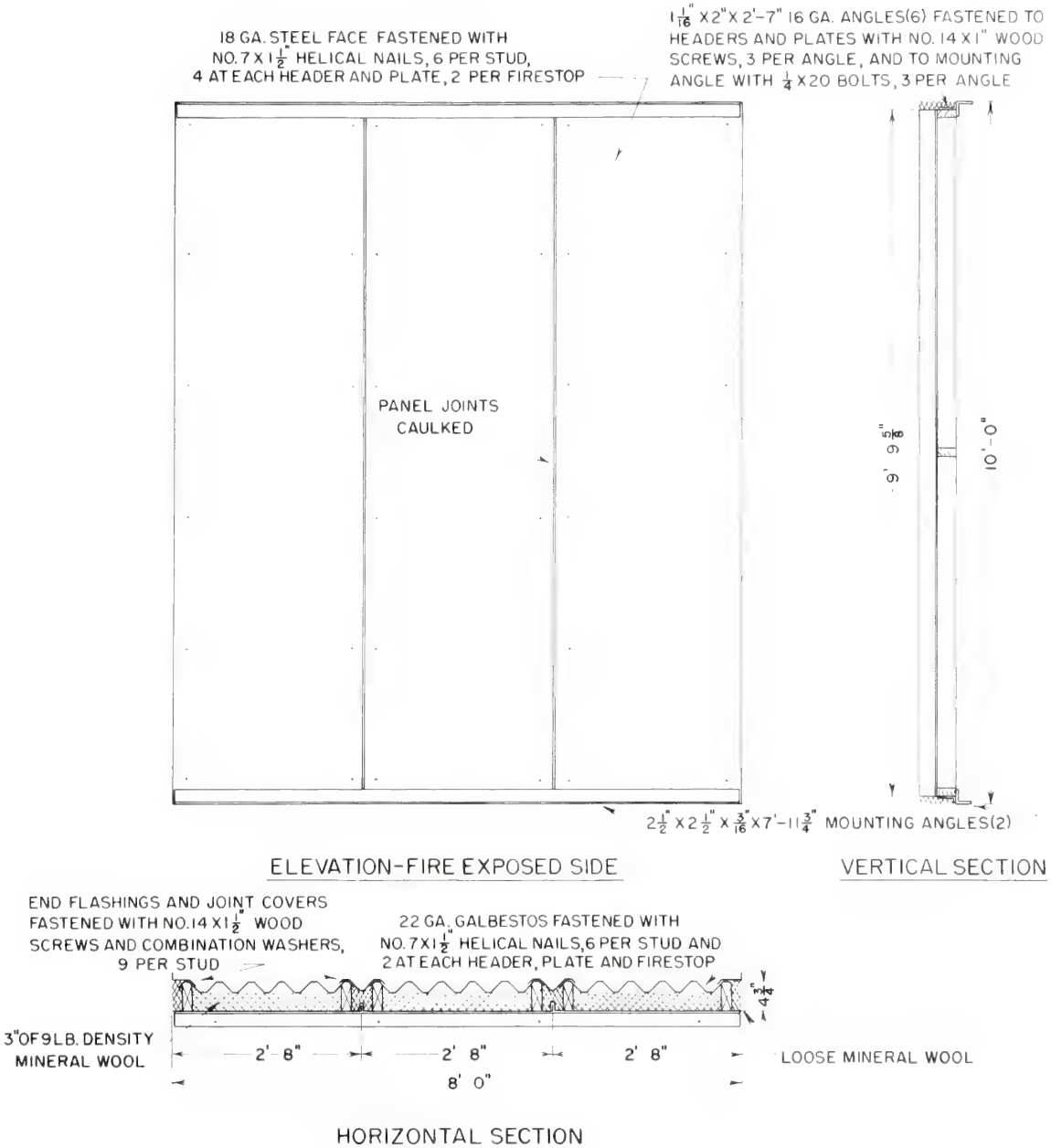


FIG. 3 CONSTRUCTION DETAILS OF TEST PANEL NO. 3

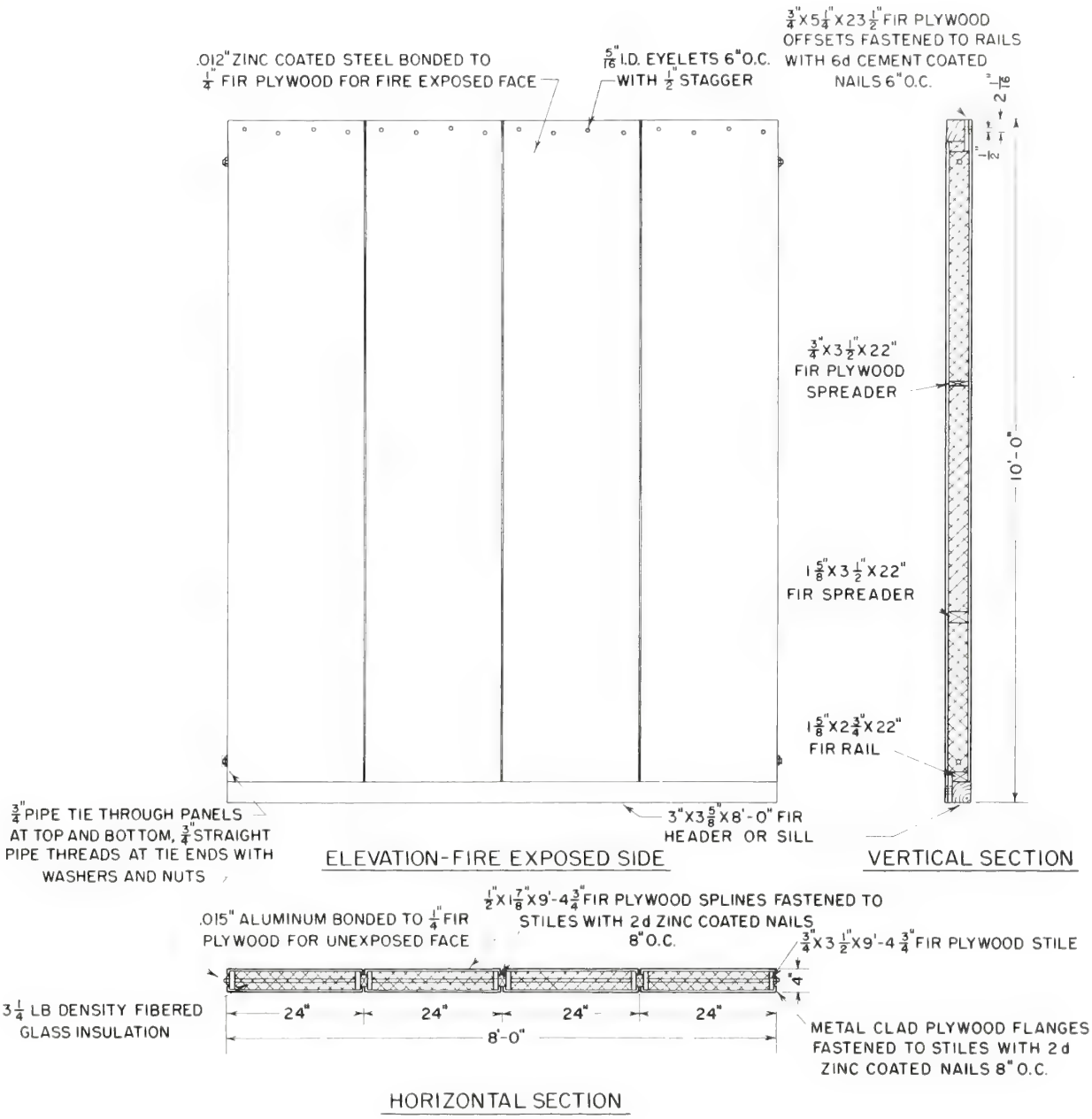


FIG. 4 CONSTRUCTION DETAILS OF TEST PANEL NO. 4

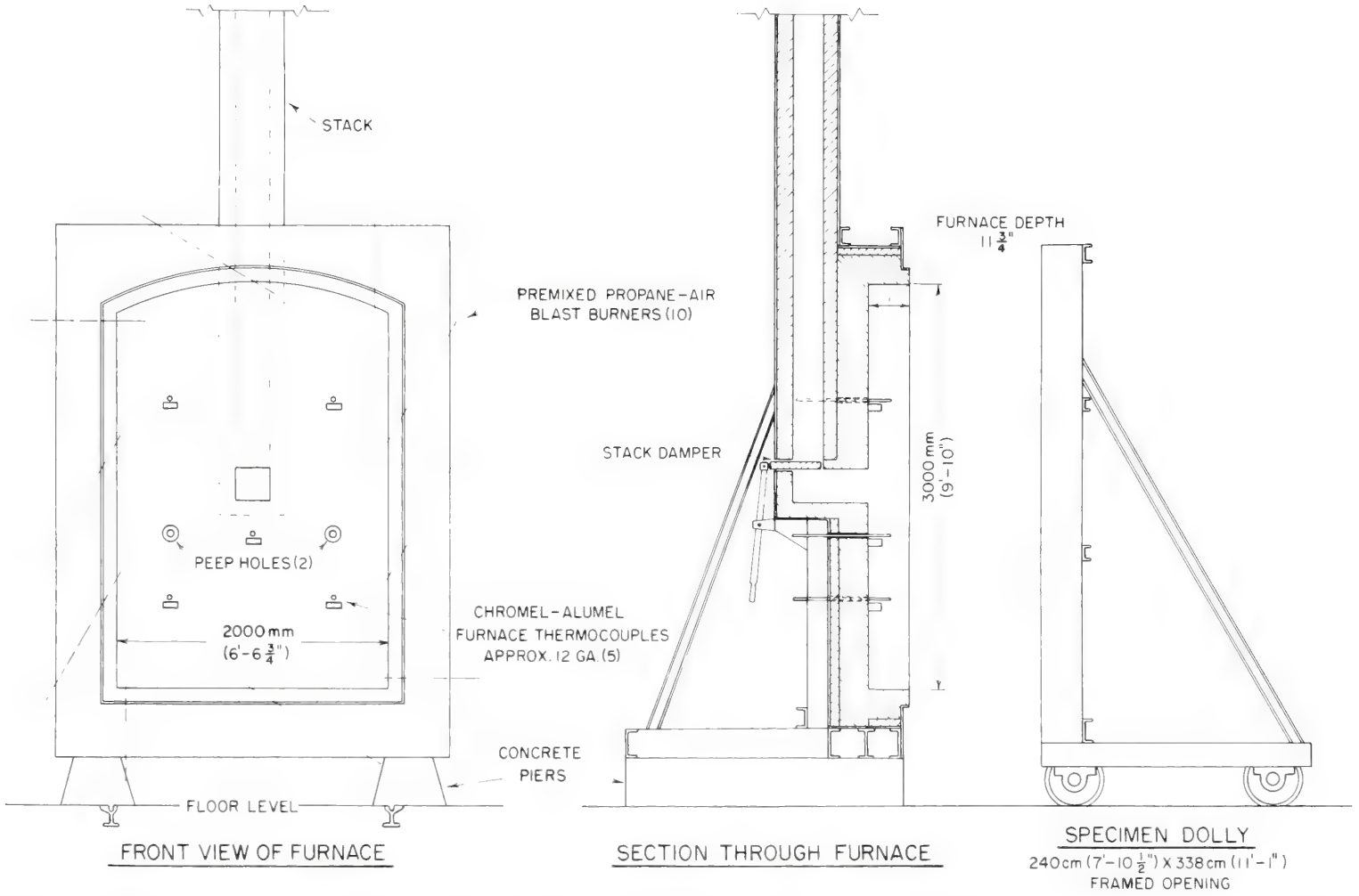


FIG. 5 PANEL TESTING FURNACE - T.N.O. FIRE RESEARCH LABORATORY - DELFT, HOLLAND

STEEL ENCASED INSULATED FURNACE LINED WITH FIREBRICK

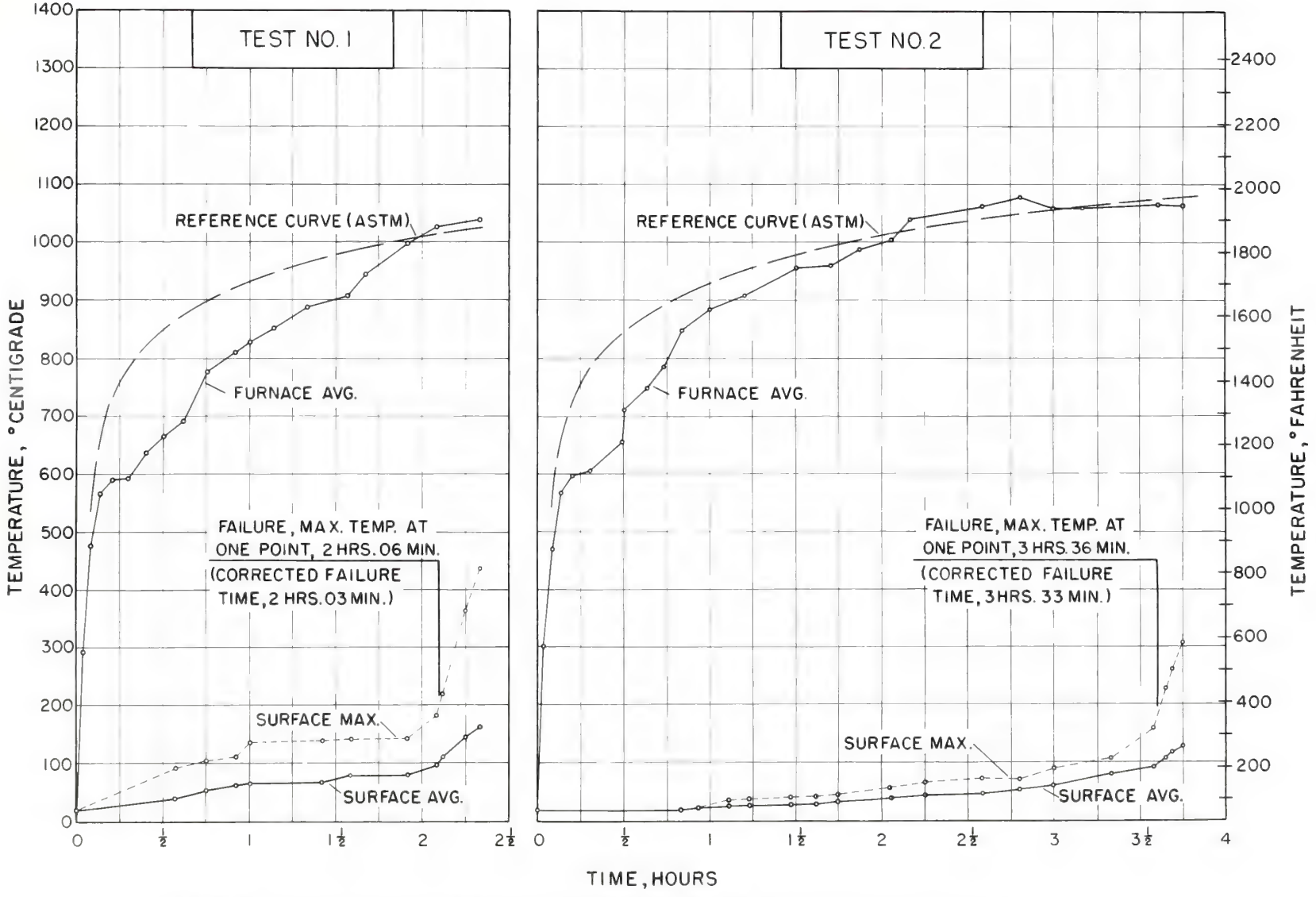


FIG. 6 TIME-TEMPERATURE CURVES FOR TESTS NO. 1 AND 2

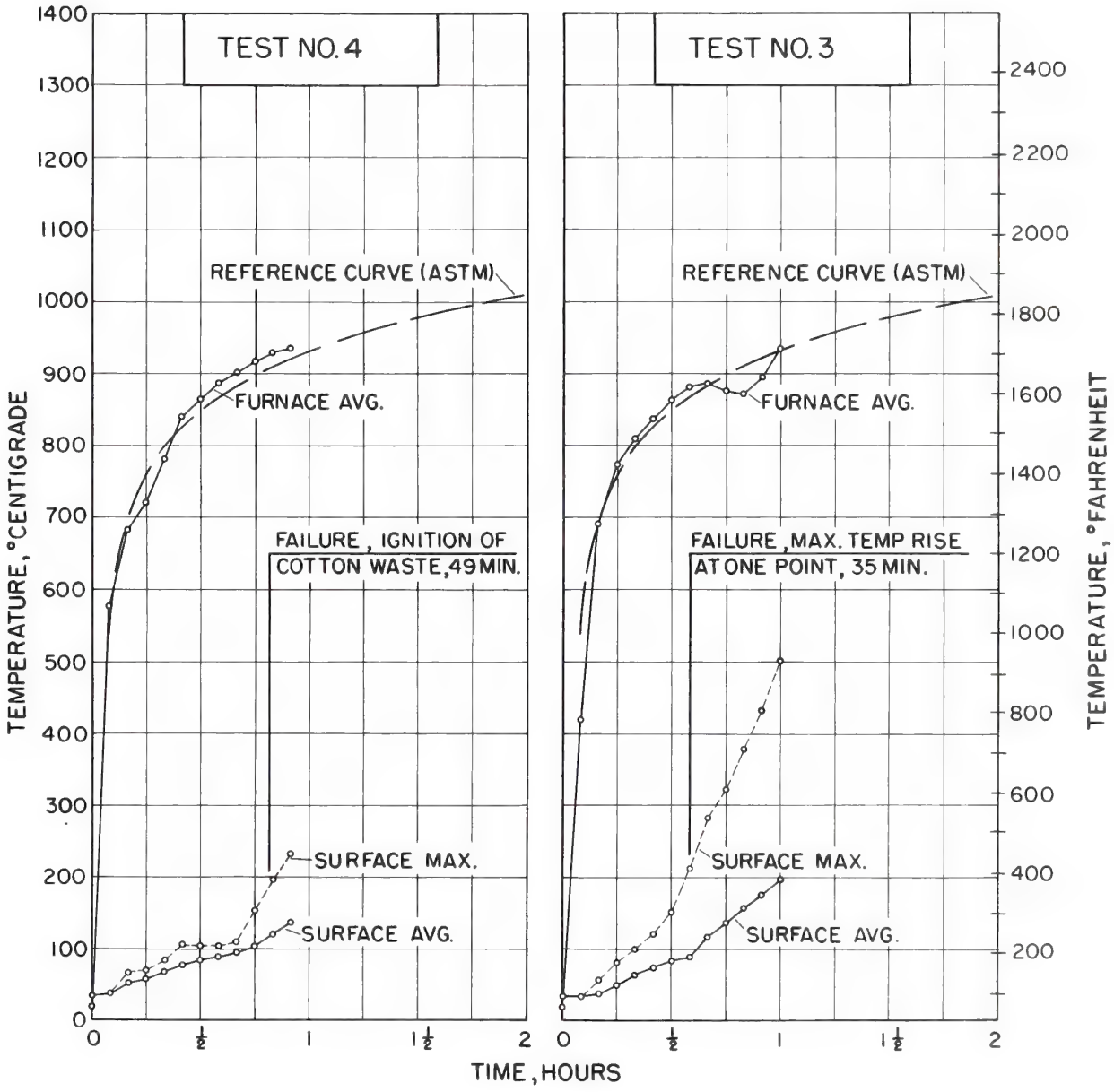


FIG. 7 TIME-TEMPERATURE CURVES FOR TESTS NO. 3 AND 4

Fig. 9 Transparent surface of specimen during test 1.

Fig. 9. Exposed surface of specimen immediately after end of test 1.

Fig. 14. Unexposed surface of specimen at start of test 3.

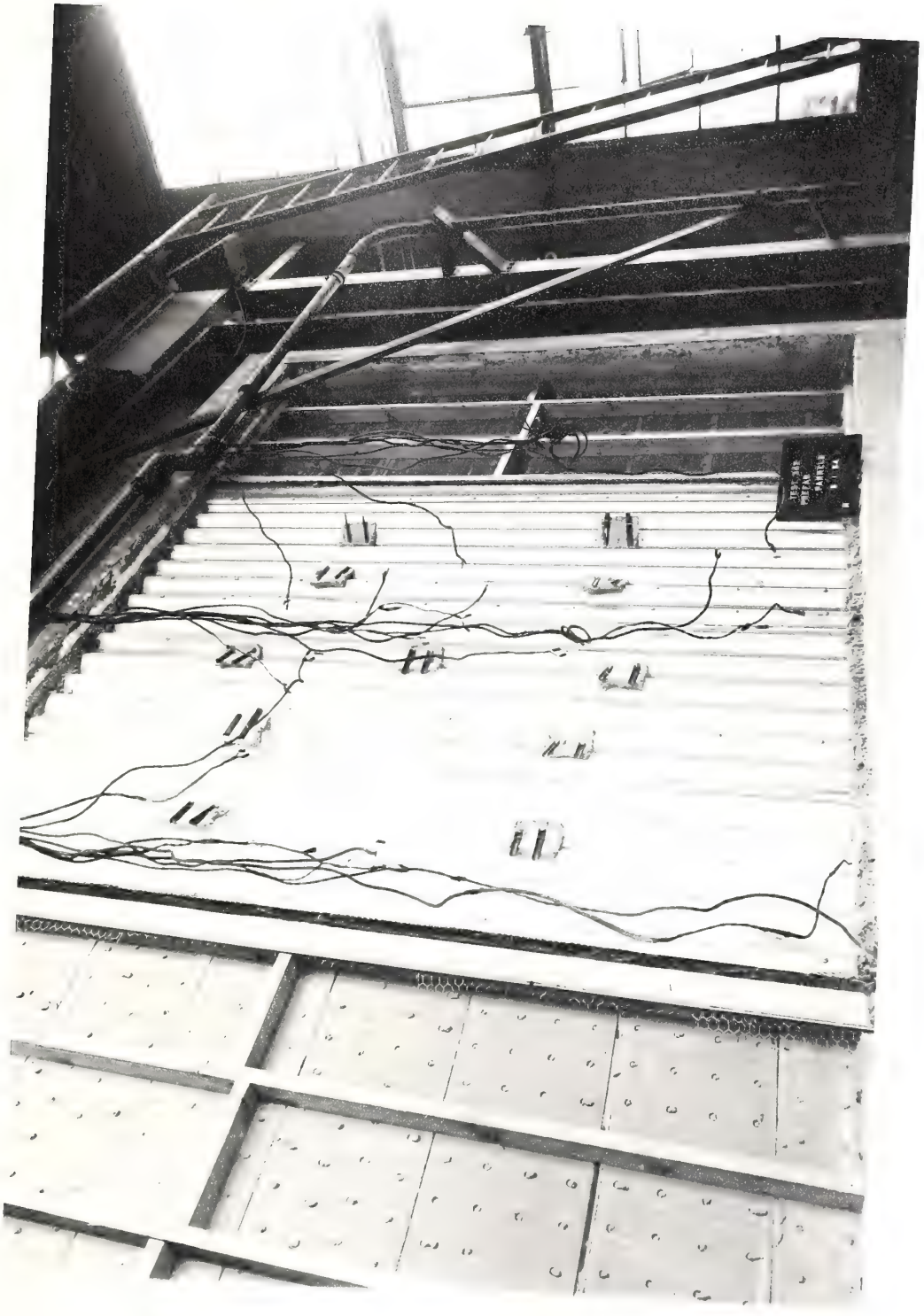


Fig. 11. Footprint surfaces of specimens at 43 min in test 3.

Fig. 14. Details of specimen from test 3, after removal from test frame.

Fig. 17. Unexposed surface of specimen at start of test 4.

Fig. 14. Unexposed surface of specimen at 75 mls in test 4, showing wrinkled condition of aluminum surface and flame through joints.

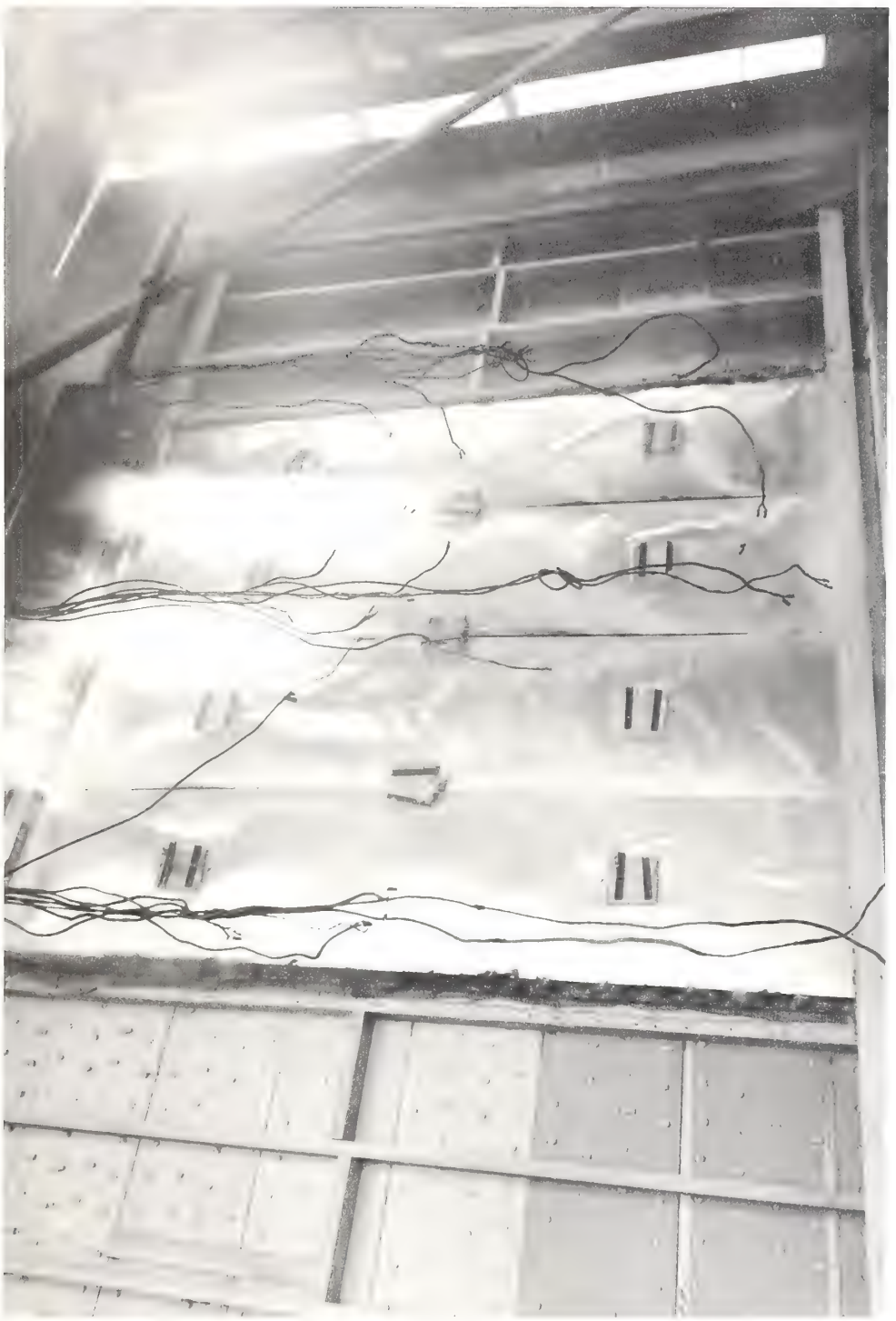


Fig. 1). Remains of specimen from test 4, after removal from test frame.